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UNITED STATES DEPARTMENT OF AGRICULTURE
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BULLETIN No. 72

NAPIER GRASS (Pennisetum purpureum)

A PASTURE AND GREEN FODDER CROP FOR HAWAII

By

C. P. WILSIE, agronomist

and

M. TAKAHASHI, assistant in agronomy

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By C. P. Wilsie, *agronomist*, and M. Takahashi, *assistant in agronomy* [1]

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INTRODUCTION

Napier grass (*Pennisetum purpureum*), also known locally as elephant grass or Napier fodder, was introduced into Hawaii in 1915 by the Hawaii Agricultural Experiment Station. This large canelike perennial is a native of tropical Africa (*1, p. 334*),[2] where it naturally attains a height of 6 to 8 feet.

Experiments in different parts of South Africa (*6, p. 60; 8, p. 8*) showed Napier grass to be of especial value as a green-fodder crop and capable of being made into silage of good quality. All kinds of livestock and particularly horses were fond of the grass and it produced enormous yields. Once the valuable features of this tropical grass became known, its use spread rapidly. Napier grass became common in the extreme southern part of the United States, various countries in South America, Australia, and subtropical and tropical regions the world over.

Investigation by the Florida Agricultural Experiment Station on the agronomic possibilities of the grass, reported by Thompson (*11*), indicated it to be of great promise as a forage crop. At the present

[1] The authors are indebted to D. W. Edwards of the chemistry division, Hawaii Agricultural Experiment Station, for the chemical analyses reported in connection with this investigation.
[2] Italic numbers in parenthesis refer to Literature Cited, p. 17.

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time Napier grass is widely used in Florida, both as silage and as a green-fodder crop. Its use in the States, however, is limited by the length of the growing season. It is only in the frost-free sections that it finds its most efficient use, for the true perennial nature of the grass is one of its very desirable characteristics.

Introductions into Hawaii were made, both from the Bureau of Plant Industry, United States Department of Agriculture, and from the Florida Experiment Station. After repeated trials at the Hawaii Experiment Station and at the University of Hawaii (7) had shown its adaptability, its high nutritive value as a forage, and its exceptional yielding ability, the grass was distributed to interested ranchers and dairymen throughout the Territory. At first it was grown mainly in small areas and used as a soiling crop. Later it was found to possess desirable pasture possibilities and larger acreages were planted. One ranch has had as much as 600 acres planted to pure stands of Napier grass, all of which was used for pasturing beef cattle and horses.

At the present time Napier grass finds wide use both as a pasture crop for beef cattle and as a soiling crop for dairy cows. For low to medium elevations where the climatic conditions are favorable, there is probably no forage crop now under cultivation that will produce roughage of good quality as economically as will Napier grass. Its distinctive features are aggressiveness, long life, drought resistance, high productivity, and ability to recover after being cut. The acreage of the grass could well be extended on many of the ranches in the Territory.

DESCRIPTION

Napier grass is a leafy, branching, vigorous-growing perennial, attaining, under favorable conditions, a height of 10 to 15 feet at maturity. It has a strong, extensive fibrous root system which enables the plant to become quickly and permanently established in the soil. The leaf blades are usually 1 to 1½ inches wide and 2 to 3 feet long. The leaf carries a conspicuous ligule consisting of a fringe of fine hairs about three-eighths of an inch in length. Tillering in this species is profuse, and often as many as 50 to 100 stalks are produced from a single plant. When the plants approach maturity numerous fine branches appear, growing out from the leaf axils of the main stems. These branches as well as the main stems bear terminal condensed panicles or seed heads which are golden yellow to tawny in color and from 5 to 10 inches in length. The inflorescence is made up of a large number of spikelets borne singly or in groups of 2 or 3 on short branchlets, the branchlets being arranged spirally on the central axis. Each spikelet consists usually of a single fertile terminal floret and a second empty lemma or sterile floret, together with a pair of outer glumes of unequal length. The group of spikelets on each branchlet is subtended by an involucre of bristles which are longer than the spikelets and arranged in a whorl. This involucre of bristles falls with the matured spikelets and evidently aids in the dissemination of seed by the wind and by animals.

It has been observed that when blooming begins the stigmas emerge from 2 to 4 days before the stamens. This, it seems, would tend to promote cross-pollination and may account in part for some of the partial sterility observed in this species. A botanical description of *Pennisetum purpureum* has been given by Hitchcock (*4, p. 679*), an

agronomic description by Piper (*10, p. 21*), and descriptions of the genus *Pennisetum* by Phillips (*9, p. 167*), and by Bews (*1, p. 241*).

VARIETIES OF PENNISETUM PURPUREUM

Besides the Napier variety, Bews (*1, p. 334*) describes a taller-growing type, known in Africa as elephant grass, which is typical of the tropical high-grass savannas of central Africa. Pentz (*8, p. 8*) mentions a variety called locally "Umfufu", which he says is only another strain of the same species, having narrower leaves and a taller growth. Possibly these two just described are one and the same variety.

Two varieties have been introduced into Hawaii—Napier and Merker. Merker grass was introduced as a distinct species, but is recognized today as merely a different strain of *Pennisetum purpureum*. Both of these grasses are spoken of as elephant grass, although the term was formerly used principally for the Napier variety.

DISTINGUISHING FEATURES OF THE NAPIER AND MERKER VARIETIES

Napier grass is characterized by its wide, bright green leaves; its slightly decumbent growth in the early stages; the reddish appearance of its stems, particularly in very early growth; and its thick, somewhat soft stalks present until the plant approaches maturity. The growth rate of Napier grass is somewhat slower than that of Merker grass, and maturity comes considerably later. The Napier-grass plants tend to tiller more, however, and become more leafy, thus making up for slower growth. The total amount of dry matter produced per year is usually equal to or greater than that produced by Merker grass. Napier grass blooms in the autumn and winter and seldom at any other time during the year. It seems to set seed but rarely in Hawaii and has not been known to produce seed in the field to any extent. Figure 1 shows a typical growth of Napier grass about 60 days old growing at the Hawaii Experiment Station.

Merker grass has somewhat narrower leaves than Napier grass and appears to have a rather blue-green color. It has a slightly more upright growth in the early stages, less red pigment appearing in the stems, and finer and harder stalks as the plant approaches maturity. It has a very rapid growth rate and a quick recovery after cutting. Merker grass often begins to bloom 60 days after planting and has been known to reseed itself readily in the field. Blooming is more profuse than in Napier grass, particularly during the summer months. Its more favorable seeding habit is possibly of some agronomic importance in propagation, although for forage purposes both of these grasses are propagated almost entirely by vegetative means. A typical growth of Merker grass, in which blooming has begun at an age of 60 days, is shown in figure 2.

In spite of the characteristic differences possessed by these two varieties, at times, particularly in old stands of grass, it becomes difficult to distinguish between them. If they are grown side by side, however, from seedling stage to maturity, it is usually easy to identify either. The more pronounced reddish color of the stems, observable in new plantings, is one of the most characteristic features of Napier grass. The semiprostrate early growth is also distinctive in this variety. In the more mature stages the Napier grass is more leafy

in appearance, the leaves are wider, and the stalks are softer and thicker than those of the Merker variety.

CLIMATIC REQUIREMENTS

Napier grass is truly a tropical species, but it is very adaptable in nature and can be grown successfully in the subtropics and even in

FIGURE 1.—Napier grass 6 feet in height 60 days after cutting.

the warmer sections of the Temperate Zone. The yields of grass will vary with the length of the growing season. One or two cuttings may be made per season in the cooler sections where it is grown, while 5 to 7 cuttings are common in the tropical regions. In Hawaii it is adapted to the climatic conditions found at elevations of from sea level up to about 4,000 feet. At the higher limit of these elevations the growth is much slower and the plants are much smaller, ideal conditions being found only below 2,500 feet. According to Bews

(*1, p. 334*), Napier grass is easily injured by frosts. Observations in Paraguay (*6, p. 60*), however, indicate that frost injury does not materially damage the grass for feeding purposes. It was found that although frost had injured the tips of the grass badly, the cattle relished the fodder and suffered no ill effects from eating large quantities of it. Napier grass is exceedingly drought-resistant and although little growth is made during an extremely dry period, the grass

FIGURE 2.—Merker grass in bloom 60 days after cutting.

recovers promptly whenever moisture conditions are again favorable for growth.

SOIL REQUIREMENTS

Napier grass has been grown successfully on a wide range of soil types in various parts of the world. Langer (*6, p. 60*) reports good results even on very poor sandy soils, in South America. The tonnage of material harvested during a period of years with such a rank-growing

crop as Napier grass necessarily means the removal of a considerable quantity of the available plant nutrients from the soil. Soils of good fertility, then, are of course desirable, unless liberal quantities of fertilizer can be used to supply the lacking constituents in the poorer soils. Most Hawaiian soils are suitable for the growing of Napier grass with the exception of some of the beach sands which have a high brackish water table, and some of the extremely heavy plastic clays which are poorly drained. Plats located at the Hawaii Experiment Station on a heavy clay bottom-land soil showed a marked yellowing of plants and a lower forage yield following a period in which heavy rains had flooded the land and water had stood for but a few hours on the plats. Many of the upland residual silt loams and clay loams, fairly fertile and well drained, as well as the medium to deep ash soil types are quite suitable to the growing of this crop.

Napier grass responds readily to fertilizer treatments on many Hawaiian soils. At the university farm, Manoa Valley, on fields that have been under crop rotation and on which green-manuring crops have been grown extensively, experiments now in progress are showing a marked response to the addition of nitrogenous and phosphatic fertilizers. Data obtained by Chung at the Hawaii Experiment Station (*2, p. 30*) show definite increases in yield from the application of 450 pounds of sodium nitrate per acre. A demonstration carried out through the cooperation of the Agricultural Extension Service of the University of Hawaii with a ranch on the Island of Kauai, reported by Krauss (*5, p. 38*), showed remarkable results from the use of 400 pounds of superphosphate per acre. The fertilized area was ready for pasturing in 5 months from the date of planting, while the unfertilized areas required at least 8 months or more before the cattle could be turned into the paddocks. Exact information on the use of fertilizers for Napier grass is very meager, and further investigations are needed on which to base specific recommendations for local areas.

PREPARATION OF THE SOIL

Although Napier grass is aggressive and perennial in nature, competing very well with most weeds, it becomes well established in perfect stands only if planted in a thoroughly prepared seed bed. On new land or land that has been out of cultivation for some years, several plowings may be necessary. The soil should be allowed to aerate thoroughly after the first plowing, and it should be disked several times to kill as many weeds as possible. This procedure of plowing and disking should be repeated once, twice, or more if necessary, in order to get the soil in a good physical condition as well as to rid it of weeds which will come up after the first plowing. On more improved lands it may be that one plowing will be all that is essential. Thorough harrowing, however, is bound to pay, for if the plantings are weedy a good stand is hard to establish and maintain. Time spent in preparation of the soil is usually well repaid in the subsequent ease of management and the greater yields obtained.

METHODS OF PLANTING

Napier grass is propagated largely by vegetative means, either using stalk cuttings or root-clump divisions. Stalk cuttings for planting are best secured from a field which has been cut a few months previous

to the time the planting material is needed. Well-developed hard stalks are best, not less than 3 or 4 months of age and not older than 8 to 12 months. The stalks at this stage are well supplied with buds located at the nodes or joints just beneath the leaf sheaths. Seed canes may be planted full length or cut into pieces having from one to several nodes. Unless planting material is very scarce, it is advisable to plant only cuttings having at least 2 or 3 nodes each or, better still, canes with 4 or 5 nodes. A very successful method is to cut seed canes into lengths of 3 to 5 feet and lay the pieces end to end in the bottom of furrows plowed out about 4 feet apart. The furrows are then filled, covering the canes with 3 or 4 inches of soil, and the grass soon germinates. With this method of planting, a plant should appear at intervals of from 12 to 18 inches, or less, and a good stand should thus be obtained under favorable growing conditions.

When planting on irrigated land the furrows may be made deeper than is necessary for good coverage. The seed canes are planted in the bottom of the furrow, covered with 4 or 5 inches of soil, and the furrow is not completely filled. The grass can then be irrigated, using the planting furrows to carry water, and germination is hastened by applying water a day or two after planting.

Another method of planting, if less seed material is available, is to use stalk cuttings with 2 nodes each and to space them about 2 feet apart in the row, planting horizontally in the bottom of furrows. If single-node cuttings are used, the pieces may be pushed into the soil at an angle of about 60° with the surface of the ground. This method is not recommended unless planting material is very difficult to obtain and good care can be given to the field after germination starts.

PLANTING WITH ROOT CLUMPS

A large plant with 50 or more tillers offers a good source of material for planting with root-clump divisions. After the top growth has been removed the root clump may be dug out and divided into a large number of pieces, each of which may be planted separately. If this system of planting is used, rows should be spaced about 4 to 6 feet apart and root divisions planted in hills about 2 feet apart in the row. There is usually very little difference in yields obtained by either the root- or stem-cutting methods.

CULTIVATION AND IRRIGATION

New plantings of Napier grass should be cultivated at frequent intervals until the grass has become well established. If the field is kept free from weeds until the Napier grass gets a good start, little trouble will be had, for this crop competes very successfully with the most persistent types, including Japanese nutgrass (*Cyperus rotundus*). While the Napier grass does not kill the nutgrass it seems to be affected but little by the latter. Cultivation between the rows at intervals throughout the year after the grass is cut has been found to be good practice. The root system tends to become heavy and a more or less sod-bound condition results. At intervals of 6 months or a year a good plowing or subsoiling treatment between the rows would doubtless produce very favorable results. In pastures the cultivation treatments are usually limited to the earlier stages in the establishment of the stand of grass with possibly an occasional subsoiling or

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plowing to rejuvenate old stands. More of this sort of treatment would no doubt be well worth while.

With a well-distributed rainfall of from 50 to 100 inches per year excellent yields can be obtained. In many regions where Napier grass can be grown, however, the rainfall is not nearly so heavy nor as well distributed. In these drier sections, having an annual rainfall of from 20 to 40 inches, irrigation is essential for high yields. A furrow system is quite satisfactory, applying water about every 10 days during the dry weather. Napier grass will withstand extremely dry conditions, remaining somewhat dormant and recovering immediately when enough moisture is supplied, but its growth and yield are greatly reduced unless sufficient moisture is available throughout the season. This can be understood readily when one realizes that Napier grass cut for green fodder contains from 85 to 90 percent of water, and that from 75 to 100 tons of such fodder are often cut from an acre in a single year.

UTILIZATION AS A SOILING OR FODDER CROP

Napier grass grown as a green feed (soiling crop) for dairy cows to be fed in the barn or feed lot can be handled in much the same way as a crop of corn or sorghum. The first cutting may be made when the grass has reached a height of 4 to 5 feet. Under favorable growing conditions this first cutting can be made about 60 to 80 days after planting, depending on the temperature, length of day, and available moisture present. It has been observed that a much more rapid growth takes place during the warmer months, particularly when the days are longest.

The grass may be cut close to the ground level, for the new growth comes out from the crown of the plant. The grass should not be allowed to mature, for the stalks begin to lignify rapidly and the digestible nutrients per ton of fodder are lowered markedly. The protein content in particular decreases rapidly and the fiber increases as the plant approaches maturity. Some dairymen in Hawaii cut Napier grass when it stands about 3 feet in height. At this stage it is very palatable and has a higher protein content than most grasses cut for green fodder. If the grass is cut in a very immature stage continuously over a long period the yield may be lowered and the root reserves may become so depleted that the stand will be permanently injured.

The best stage at which to cut and the number of cuttings that should be made per year to obtain the maximum yield and palatability are not definitely known. For dairy cows, however, it is important that the grass be cut while it is still very palatable so that the stalks as well as the leaves will be eaten without much waste. If it is fed with alfalfa or other high-protein roughage, it can be fed in a slightly more mature stage than when it is the sole source of protein in the roughage. When grown under irrigation in the vicinity of Honolulu, 5 or 6 cuttings can be obtained each year and a good stand successfully maintained. Such stands should give good ratoons for 5 to 6 years or more, particularly if some attention is given to fertilization and cultivation during that period.

When the grass is succulent and soft the whole stalks can be fed without much waste. If harvested at a more mature stage, the grass

should be cut or chopped before feeding. Taking the waste or uneaten portions from the mangers of the dairy cows and feeding it to young cattle, dry stock, or horses might bring about a more efficient use of the fodder in many instances. Napier grass is probably fed most successfully with alfalfa, pigeon peas (*Cajanus indicus*), or ekoa (*Leucaena glauca*) in Hawaii.

Because of the heavy tonnage produced and the ease of growing the crop, Napier grass is one of the most economical roughages that the dairyman in Hawaii can feed.

NAPIER-GRASS PASTURES

Both Napier grass and Merker grass are used quite extensively for pasture purposes. The use of these large, coarse fodder grasses for pasturage seems to be a rather recent idea. At least it presents a far different picture from the usual conception of a pasture in the Temperate Zones. Napier grass, however, does make a very successful

FIGURE 3.—Napier-grass pasture under a system of rotational grazing.

pasture at the lower elevations where there is sufficient rainfall throughout the year. These pastures have been particularly outstanding in the Kaneche district on Oahu and in the Hanalei district on Kauai. Certain locations on Maui, especially in the Kipahula district and the lower slopes of Haleakala, are well adapted to the growing of Napier grass.

Ranchers in the vicinity of Hilo, as well as in the Kona district of Hawaii, could no doubt benefit greatly by the establishment of more Napier pastures. Probably one of the most outstanding examples of the successful use of Napier grass for this purpose is to be found on the Princeville Plantation Co.'s ranch on Kauai. Here may be found more than 600 acres in pure stands of Napier grass, the paddocks ranging in age from recent plantings to others more than 12 years old. The horses as well as the cattle on the ranch are fed almost entirely on Napier grass and they keep in excellent condition. The paddocks are grazed heavily, the cattle being turned in only after the grass has reached a height of 6 feet or more. After the pasture has been well

eaten down, the cattle are put into a paddock which has been resting or recovering. Thus fresh paddocks are available for pasturing at successive intervals and the stand of grass maintained with a high productive capacity. Other ranches in the Territory have had similar success and Napier grass has definitely shown its value as a pasture grass (fig. 3).

ROTATIONAL GRAZING

Napier grass, like other grasses in improved pastures, should not be grazed continuously. In order to maintain a good stand and high level of productivity, a grass must be allowed to rest and recover after heavy grazing. The root reserves of a plant can be built up only when the plant is allowed to make some top growth and manufacture carbohydrates in its leaves. If the leaves are continually being removed, root reserves become depleted and the plant is easily killed. This is

FIGURE 4.—An excellent Napier-grass pasture which has been properly grazed.

especially important with grasses of the bunch-grass type of growth, and Napier grass belongs in this group.

The ranch should be divided into a number of paddocks and these grazed in rotation. Each paddock may be heavily grazed for a short period and then rested for a number of weeks so that the grass will have ample time to recover and accumulate a good supply of fresh top growth.

The present method of pasturing Napier grass is to allow the grass to become fairly mature before the cattle are turned in. Many of the coarser and harder stalks are left uneaten, with consequent considerable waste. It is believed that by the proper method of rotational grazing of paddocks, pasturing heavily when the grass is fairly young and succulent, removing the cattle to another paddock before the grass has become permanently injured by close grazing and tramping, and a more frequent grazing of all paddocks for a shorter period each time a paddock is pastured, more efficiency and better quality feed would be obtained. The carrying capacity of a Napier-grass pasture under favorable growing conditions is high. One rancher estimates that one

mature head of beef cattle per acre per year can be fattened on his Napier-grass pastures. Compared with other pasture plants, it can readily be seen that Napier grass offers extremely good possibilities wherever it is well adapted (fig. 4).

EXPERIMENTS ON THE YIELD OF NAPIER GRASS

In May 1932 an experiment was begun at the university farm to determine the comparative yields of four grasses grown under irrigation. Plats of Napier and Merker grasses, Sudan grass (*Sorghum vulgare* var. *sudanense*), and guinea grass (*Panicum maximum*) were planted. A crop of piegeonpeas and mixed legumes was plowed under a few months before planting the grasses, but no manure nor commercial fertilizer was applied to this field.

Stem cuttings were used for planting in case of Napier and Merker grasses, root-clump divisions in case of guinea grass, and seed sown

FIGURE 5.—Harvesting Merker-grass plats at the University of Hawaii farm, June 1933.

at the rate of 20 pounds per acre in case of Sudan grass. Two spacings were used with each grass. With the Napier and Merker grasses, rows were spaced 4 feet and 6 feet apart with plants 2 feet apart in the row. The guinea and Sudan grasses are much smaller in growth and the rows were spaced 2 and 3 feet apart (fig. 5).

Each grass was cut at what was considered to be the proper stage for feeding as a soiling or green-fodder crop. Sudan grass was cut when in early bloom, guinea grass when starting to bloom, and Merker and Napier grasses when the plants were about 5 feet in height. At this stage the Merker grass was often just starting to bloom and during the winter months the Napier grass sometimes showed a few flowering heads. Subsequent cuttings were made at as nearly the same stage as could be determined by observation. The yields of green forage harvested, air-dry forage, and percentage of air-dry forage in the green material harvested for the first year of the experiment are given in table 1.

TABLE 1.—*Yields of Napier and other grasses (1 year's results)*

Grass	Cuttings per year	Green weight per acre	Air-dry forage	Air-dry weight per acre
	Number	*Tons*	*Percent*	*Tons*
Napier	5	87.75	12.3	10.80± [1] 0.96
Merker	7	59.77	14.3	8.54± .76
Guinea	5	48.20	23.4	11.28± 1.01
Sudan	8	48.97	21.0	10.30± .92

[1] Standard error in tons for a mean of 6 plats. All yields given are calculated from six 1/40-acre plats of each variety, after the border rows were removed.

It will be noted that on the green basis Napier grass produced a much higher yield than did the other grasses in the test. As table 1 shows, however, the Napier grass had the lowest percentage of air-dry forage of any of the four, and on the dry basis guinea grass produced slightly more and Sudan grass only slightly less total weight per acre. The yield of Merker grass was somewhat lower than the others, but not significantly lower than that of Napier grass. It was observed that throughout the season the Merker grass grew more rapidly than the Napier grass and as a consequence two more cuttings were possible. Each cutting of Napier grass, however, gave a larger yield than the cuttings of Merker grass, and the total yield during the year was slightly higher.

It was observed that dairy cows liked the Sudan and Napier grasses somewhat better than the Merker and guinea grasses. The Napier grass had softer stems and was fed with less waste than the Merker grass.

PERSISTENCE OF STAND

At the end of the first year of this experiment the grasses were all in excellent condition except the Sudan grass, which had become somewhat thinned out. Because of its shallow root system this species suffered considerable injury during the cutting process, especially if dull sickles were used, many of the plants of Sudan grass being pulled up or at least partially broken loose from the soil, with the result that after a few months the stand was considerably weakened. However, a remarkable total yield was obtained from Sudan grass in this experiment.

The guinea grass seemed to be in excellent condition, but the yields were falling off rapidly before the end of the year. Although the total yield of the guinea grass was higher than that of any of the other grasses, nearly one half of this yield was produced in the plant crop. This grass might be used more successfully as a pasture grass, for its ratoon growths are too small to cut satisfactorily, requiring about twice as much time for harvesting as does Napier or Merker grass. All plats of Napier and Merker grasses showed excellent stands at the end of the year and offered promise of maintaining a high level of production for future cuttings. A need for fertilizer was apparent, however, in practically all cases.

The true perennial nature of the Napier and Merker grasses with their strong spreading root systems makes for permanence, and it is probable that with proper cultivation, plenty of moisture, and the addition of fertilizers when needed, excellent yields could be maintained for 5 to 6 years from a single planting.

EFFECT OF SPACING ON YIELD

Yields of Napier grass and of Merker grass grown in rows spaced 4 and 6 feet apart are shown in table 2.

TABLE 2.—*Effect of spacing on yield of Napier and Merker grasses*

Grass	Spacing between rows	Green weight per acre	Air-dry weight per acre
	Feet	*Tons*	*Tons*
Napier	4	85.14	10.44
	6	90.36	11.14
Merker	4	57.56	8.25
	6	62.31	8.84

The yield appears to have been affected but little by difference in spacing. In each case, however, a slightly higher yield was obtained with rows spaced 6 feet apart. These differences are probably too small to be of any significance. Within this range of spacing at least, it appears that the plants tend to fill all of the available space. Close spacing will prevent profuse tillering, and, although a 4-foot-row spacing gives 50 percent more plants per acre, the yields, according to these data, are not higher but actually slightly lower.

YIELDS OF NAPIER AND MERKER STRAINS

Observations on the growth habits of the elephant grasses have indicated that there are a number of types or strains. In the early spring of 1932 a plant found growing in a Merker-grass pasture near Kaneohe, Oahu, was brought to the experiment station for observation and testing. Cuttings were made and within a few months considerable planting material was available for experimental use. This particular strain from the one plant had remarkable tillering ability, a most rapid growth rate, and a darker color than the ordinary Merker type. Experiments were made to compare the yielding ability and persistence of this strain with the standard types of Napier and Merker grasses. A total of four $\frac{1}{60}$-acre plats of each variety were included in the test, with rows spaced 5 feet apart and plants 2 feet apart in the row. The yields obtained during the first year of this experiment are given in table 3.

TABLE 3.—*Yields of Napier grass and 2 strains of Merker grass* [1]

Grass	Cuttings per year	Green weight per acre	Air-dry forage	Air-dry weight per acre
	Number	*Tons*	*Percent*	*Tons*
Napier	5	80.55	10.8	8.70± [2] 0.92
Merker (strain K)	6	66.84	15.3	10.23± 1.09
Merker (strain P)	6	71.00	14.8	10.54± 1.12

[1] These yields represent means of 4 replicated plats of $\frac{1}{60}$ acre each. The data cover a period of slightly more than 11 months. The grasses were planted Oct. 27, 1932, and the final harvest reported was made Oct. 6, 1933.

[2] Standard error in tons per acre for a mean of 4 plats. With standard errors of this magnitude, a difference in yield of approximately 3 tons per acre (air-dry basis) would be necessary to be significant.

The results given in table 3 show again that Napier grass produced the highest yield in fresh green forage. The percentage of dry matter was, however, considerably higher in the two strains of Merker grass,

and for that reason the results on the air-dry basis indicate that Merker slightly outyielded Napier grass. The air-dry weight is much the more accurate basis for the comparison of yields of forage crops, as the moisture content varies considerably in different varieties and within the same variety at different growth stages. The differences between the yields of the Napier and Merker strains, which range from 1.5 to 1.8 tons per acre per year, are too small to be of any practical significance. These data indicate then, as did those in table 1, that Merker and Napier grasses do not differ significantly in the production of dry matter during the first year of their growth. They suggest, however, that Napier grass may be more palatable than Merker grass because of its greater succulence and its higher moisture content. They show little difference in yield of air-dry forage between the two strains of Merker grass included in the test.

YIELDS IN OTHER REGIONS

Langer (*6, p. 63*), in reporting on Napier-grass trials in Paraguay, states that 3 to 6 ratoons will yield from 60,000 to 120,000 kilograms per hectare, which would be about 26.7 to 53.5 tons per acre. Reports from the Guam Agricultural Experiment Station (*3, p. 9*) give an average of 15,848 pounds per cutting per acre of green forage for Napier grass and 13,477 pounds for Merker grass. Napier grass has yielded a higher tonnage of green fodder than Merker grass during a period of 5 years. On the dry basis, however, there would probably be little difference between the two varieties.

CHEMICAL COMPOSITION

The chemical composition of a grass determines, to some extent, its feeding value. Inherent differences in composition, particularly in regard to the protein and ash constituents, are of importance. The greatest single factor in determining the chemical composition of a forage crop is probably the stage at which the plants are cut. Pasture grasses cut at a very immature stage, when most of the forage consists of leaves and tender stems, are high in protein and total ash, approaching or surpassing that found in high-protein dried roughages such as alfalfa. In the choice of a forage crop then, it is important to know if the crop can be cut at a stage when it contains a high percentage of protein and a low percentage of fiber. High yields can be obtained with Napier grass cut at a relatively immature stage, when it is very palatable and nutritious. Chemical analyses were made of samples of Napier, Merker, guinea, and Sudan grasses collected at different times during the year from the university farm plats and representing the actual condition of the grasses when they were harvested for dairy cattle feeding. The results are shown in table 4.

TABLE 4.—*Composition of fodder grasses*

Grass	Average period between cuttings	Analyses	Composition on basis of oven-dry weight		
			Crude protein	Fiber	Total ash
	Days	*Number*	*Percent*	*Percent*	*Percent*
Napier	63	13	6.84	33.78	17.48
Merker	54	13	7.17	34.46	16.30
Sudan	48	7	6.02	33.66	11.50
Guinea	62	9	4.96	33.10	16.50

The results indicate little difference in protein content between Napier, Merker, and Sudan grasses. The Napier and Merker grasses appear to have a higher protein content than does guinea grass. In crude-fiber content all of the grasses were similar, and in total ash all were similar except Sudan grass, which was considerably lower in ash than the others.

Average analyses do not indicate the variation in protein content due to seasonal growing conditions and to the number of ratoon crops that have been cut. Although ratoon cuttings were made at approximately the same stage, in any one species, it was noted that the age of the stand in the field had a marked effect on chemical composition. The effect of the age of the plats and the number of ratoon crops cut on the protein content of Napier and Merker grasses is shown in table 5.

TABLE 5.—*Protein content of plant crop and successive ratoons of Napier and Merker grasses*

Cutting	Napier grass		Merker grass	
	Crude protein	Age when cut	Crude protein	Age when cut
	Percent	*Days*	*Percent*	*Days*
Plant crop	14.18	77	15.19	70
First ratoon	9.84	64	8.23	50
Second ratoon	5.42	60	7.15	60
Third ratoon	5.39	59	5.00	50
Fourth ratoon	3.81	76	7.12	65
Fifth ratoon	[1] 7.50	65	3.88	63
Sixth ratoon			4.04	60

[1] Fertilizer was applied 10 days before this harvest, which may account for this higher percentage of protein.

The protein content of the plant crop in both Napier and Merker grasses was, according to these analyses, much higher than in the subsequent ratoon crops. Although the ratoon crops were harvested at what seemed to be the same growth stage, produced in even less time than the plant crop, the protein content after the first ratoon was rather low. The plant crop was evidently made up of a higher percentage of leafy forage with a lower percentage of stalk than appeared in later cuttings. These data indicate the futility of taking 1 or 2 analyses of a grass and upon those analyses attempting to determine the amount of protein that will be produced during a yearly period.

Seasonal conditions, the fertility of the soil, and the number of ratoon crops taken, all seem to be very important factors in determining the yearly production of protein in a forage grass. It seems likely that unless a high state of fertility is maintained, these coarse fodder grasses, particularly in their ratoon crops, will not produce the quality of forage to be most desired. Further experiments are needed to demonstrate just what can be expected in the way of maintaining a high protein content through stimulated growth by the application of fertilizers. It is probable that heavy fertilization of a crop, which produces so abundantly as does Napier grass, would be economical in the growing of high-quality forage.

Experiments in other regions, cited by Langer (*6, p. 64*), indicate that Napier grass is of very desirable chemical composition. Results of chemical analyses are given in table 6.

TABLE 6.—*Composition of Napier grass (dry basis)*

Analyses made in—	Crude protein	Ether extract	Nitrogen-free extract	Crude fiber	Ash
	Percent	*Percent*	*Percent*	*Percent*	*Percent*
Florida	14.2	2.7	45.2	29.6	8.3
New South Wales	10.4	1.5	41.7	38.0	8.4

From the relatively high protein content shown in table 6 it seems probable that the samples were taken from the plant crop when the forage was leafy and immature.

Langer states further (*6, p. 65*) that tests of the digestibility of Napier grass have shown its nutritive ratio to be 1:7.7, which compares very favorably with the better-quality grasses. Further trials on the digestibility of this grass are needed, for it must be remembered that the nutritive ratio of a grass is much narrower in an immature grass than in a mature one. For feeding young growing calves and dairy cows in milk, Napier grass should be cut at a rather immature stage, with the plants from 3 to 5 feet in height, so as to get the higher protein content, while for fattening beef cattle it might be fed at a slightly more advanced stage in growth.

SUMMARY

Napier, or elephant grass, a tall vigorous perennial, was introduced into Hawaii in 1915 and has become important as a pasture and green-fodder crop.

Its outstanding features are its aggressiveness, heavy yields, high nutritive value, and persistent growth over a period of years.

Propagation is best accomplished by the use of stalk cuttings or root-clump divisions.

Although drought resistant, Napier grass responds to abundant moisture and can be grown very successfully under irrigation.

Yields of from 50 to 90 tons of green fodder per acre per year are readily obtained under favorable growing conditions.

Napier grass may be successfully pastured if rotational grazing is practiced, allowing a period for rest and recovery in the various paddocks.

A carrying capacity of one mature beef animal per acre per year has been obtained with Napier-grass pastures under proper management.

Chemical analyses show that Napier grass has a protein content similar to that of Sudan grass when cut at the proper stage for feeding as a green fodder. The percentage of crude fiber is also similar, while the total ash is considerably higher than that of Sudan grass.

Merker grass, a strain of *Pennisetum purpureum* and similar to Napier grass, is considered slightly less palatable, particularly at the more mature stages of growth. Experiments in Hawaii so far show very little difference in yields of dry weight per acre, using these two varieties.

The greater palatability of the Napier variety, due, probably, to its more leafy growth and greater succulence, would indicate that it is usually a more desirable grass than Merker grass for forage purposes.

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